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CREATING AND TESTING A WINDOWS VERSION OF THE ADRPM ACOUSTIC MODEL

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ABSTRACT

ADRPM (Acoustic Detection Range Prediction Model) is a software program that models the propagation of acoustic energy through the atmosphere and the detectability of that energy. This paper describes ADRPM's history, capabilities, and future. A new PC/Windows version of ADRPM is presented which will soon be made available to the ground vehicle survivability community.

Acoustic Modeling

The issue of acoustic signatures often arises during the design process of ground vehicles or during vehicle upgrades. While "make it quiet" is a good start, the question is then "how quiet is good enough?" There is also the spectral question, since low frequencies propagate very differently from high frequencies. There is no sense in having a vehicle's quiet engine undetectable at short ranges if its track noise frequencies are detectable at very long ranges.

To better understand the problem and make recommendations to vehicle designers, the U.S. Army Tank-automotive and Armaments Command Research, Development and Engineering Center (TARDEC) has sponsored the development of the ADRPM software model for the last 25 years. The model has been successfully applied to the field testing of many vehicles during that time.

The continuing philosophy of ADRPM is to provide a reasonably easy-to-use model usable by non-experts, which expects only easily obtained input values. Obscure, non-measurable values such as average leaf width are not expected. New theoretical work on acoustic propagation has been added over the years when it has been shown to match real-world results, and in areas where the theory is missing or inaccurate, fitting to empirical data is done instead. Finally, ADRPM is designed only for the ground-to-ground detection case.

History of ADRPM

ADRPM began its existence in the 1970s as a simple BASIC program. Table I shows its evolution from ADRPM I to ADRPM VII, and its evolution through various platforms and programming languages. Much of the past development on ADRPM has been performed by the BBN Corporation. The version presently in use runs only on 68040-based HP-9000 Unix workstations.

Version	Year	Comments
I	1974	BASIC, by BBN Corp.
II	1975	BASIC, BBN
III	1977	BASIC, BBN
IV	1978	BASIC, paper tape support added by TACOM
V	1980	FORTRAN, University of Dayton
VI	1983	FORTRAN, Wyle Research, BBN, Prime 850 computer
VII	1988	C, BBN, PC/DOS version
VII	1993	C, BBN, 68040 HP-9000 Unix version
VII	2000	C, TACOM, PC/Windows version

Table I – Evolution of ADRPM

Capabilities of ADRPM

ADRPM has 4 primary calculations, given a certain vehicle signature, environmental conditions, and detector parameters:

1) Calculate the acoustic detection range of the vehicle
2) Given a detection distance, calculate the acoustic signature level which may not be exceeded
3) Given a distance, show the vehicle's acoustic signature, independent of detectability
4) Provide a sensitivity analysis capability, where the effect of sweeping one of the input parameters over a range can be analyzed.

Each calculation above then has 3 graphical outputs, a source spectrum, a signal-to-noise spectrum, and an attenuation spectrum. The results specific to each calculation are also presented separately in dialog boxes, such as the detection range or allowable signature level in dB.

A number of inputs are required in order to accomplish the above tasks, for the source these include:

- one-third-octave band signature values (10 Hz to 10 kHz, 31 bands)
- reference distance (source-to-microphone)
- reference height
- reference temperature, humidity, and flow resistance.

Inputs for the propagation path are:

- one-third-octave ambient noise spectrum
- temperature, humidity, wind, weather condition
- flow resistivity
- surface roughness
- barriers (distances and heights)
- foliage bands (distances and widths)

For the detector parameters:

- one-third-octave noise floor
- detector height
- probability of hit
- probability of false alarm
- detector efficiency
- detector type (human or ideal)
- detection rule (DPMAX or DPSS, described below)

Only a single, omnidirectional transducer or single human observer is modeled, and for the human detection case, the lower frequency bound is 40 Hz. The DPMAX, or d'_{max} detection rule means a single band over a certain threshold is the detection case. The DPSS, or d'_{sum} rule uses a sum of squares of detectabilities in all one-third-octave bands as its detection case. DPMAX is recommended for naïve human observers, and DPSS for skilled human observers or electronic detection systems.

Actually, multiple detection ranges are possible, such as the case where a barrier makes a vehicle undetectable for a certain range, but further out the vehicle is again detectable. ADRPM searches for solutions out to 20 km.

The exact algorithms used in ADRPM have varied over the years, and vary over the spectral bands. Details on the techniques can be found in (ref. 1). Suffice it to say that the following factors are considered in the propagation model:

- geometric spreading ($^1/_{r^2}$)
- atmospheric absorption ("classical" and molecular)
- refraction (due to temperature and wind)
- ground impedance
- surface roughness
- barriers and foliage bands.

A Windows Version of ADRPM

While ADRPM has been in continual use to the present day, it is presently only running on the Hewlett-Packard HP-9000 Unix workstation. With the encroaching obsolescence and rarity of this hardware platform, we decided to port the program over to the PC/Windows platform. Borland C++ Builder 4.0 was used for development due to its allowing relatively easy creation of GUI (graphical user interface) programs, and because the existing ADRPM was written in C. The new version runs under Windows 95, 98, NT, and 2000.

We decided early in the project to mimic the HP version's user interface and operation, thereby making the comparison between the two as easy as possible. No major modifications were done on the core analysis code of ADRPM, and the GUI follows the general layout of the original. Some changes were made to better follow Windows user-interface conventions, such as replacing Apply and Dismiss buttons with Cancel and OK buttons. Where the terms "Source" and "Target" were used interchangeably in the old ADRPM, "Source" is used consistently in the Windows version to avoid confusion.

Figure 1 shows the main screen of the HP version and Figure 2 that of the Windows version for comparison.

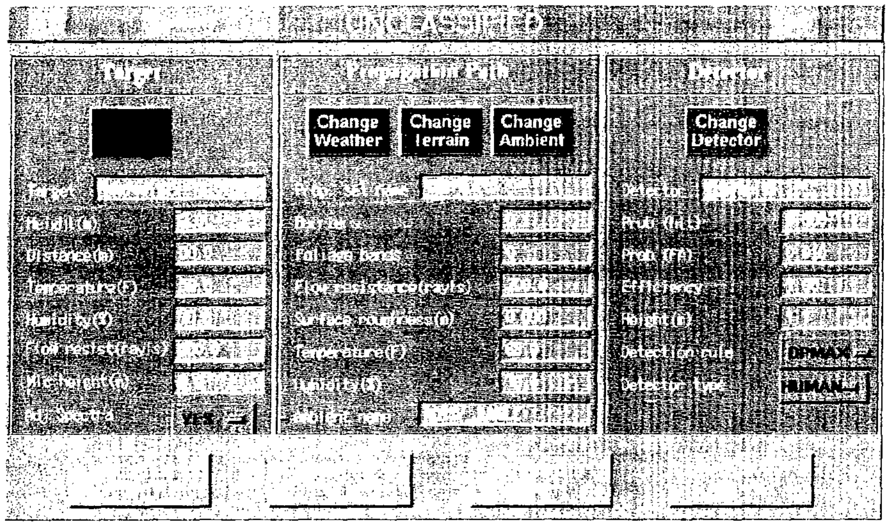

Figure 1 – HP/Unix ADRPM Main Screen

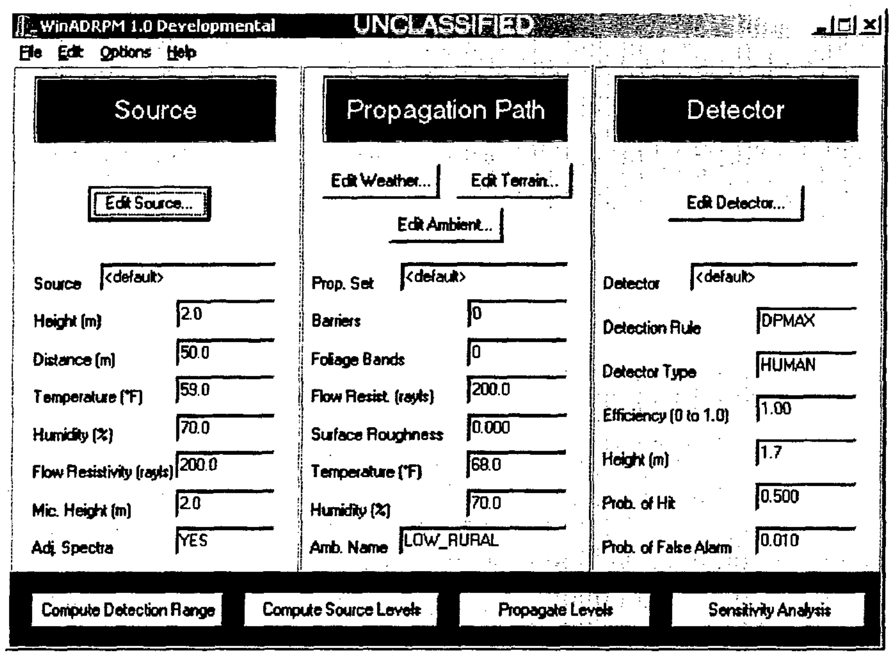

Figure 2. – PC/Windows ADRPM Main Screen

Performing some runs with heavy calculation demands illustrates the advances in hardware over the last several years. A lowly 100 MHz Pentium system calculates solutions 12 times faster than the once-mighty HP workstation.

An Example Run

Running through an example with the default inputs is probably the best way to illustrate the use of ADRPM. The main screen displays the most important input values, and provides access to 5 editing screens. Figure 3 shows the source editing screen, where the user can view the spectrum graphically, shown in Figure 4, by clicking the "View..." button. All input screens validate values as they are entered, and a bad value causes a popup window to appear showing the appropriate range for that input value. All input values are again validated upon running a detection problem. Each editing screen also allows a set of values to be loaded from or saved to a file.

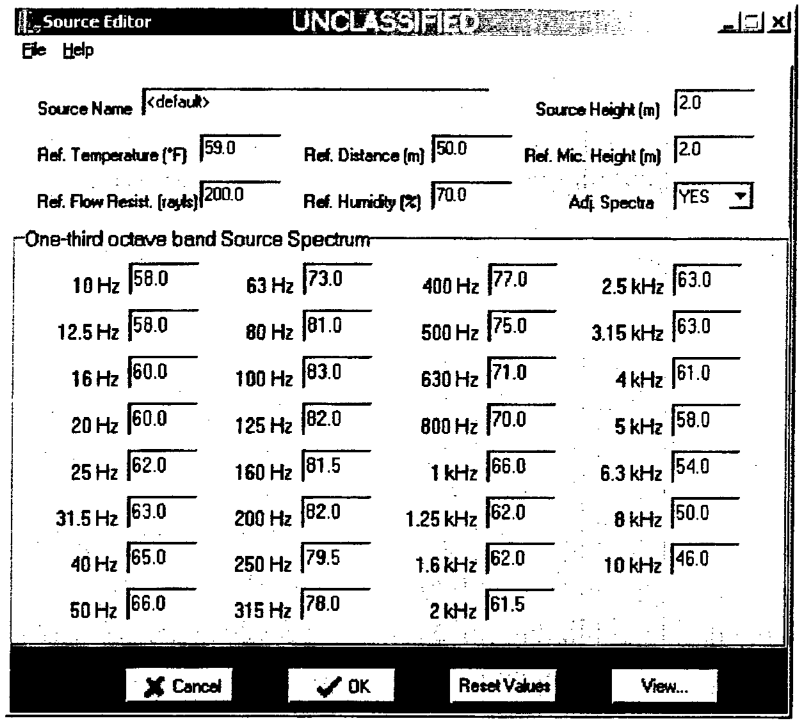

Figure 3 – Source Editor

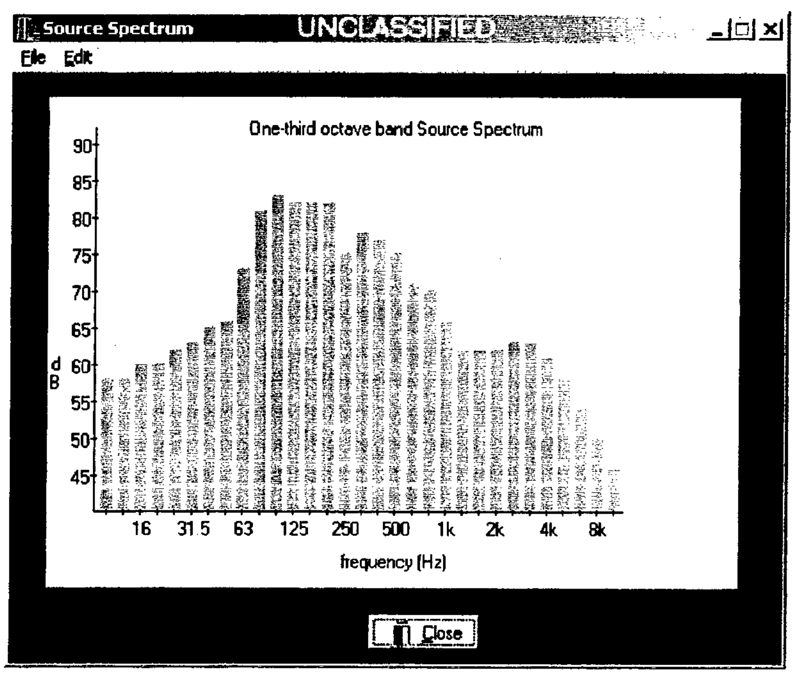

Figure 4 – Input Source Spectrum

The terrain editing screen, Figure 5, allows picking of flow resistivity and surface roughness values from drop-down lists of common materials, since many users would be unfamiliar with the numerical values used.

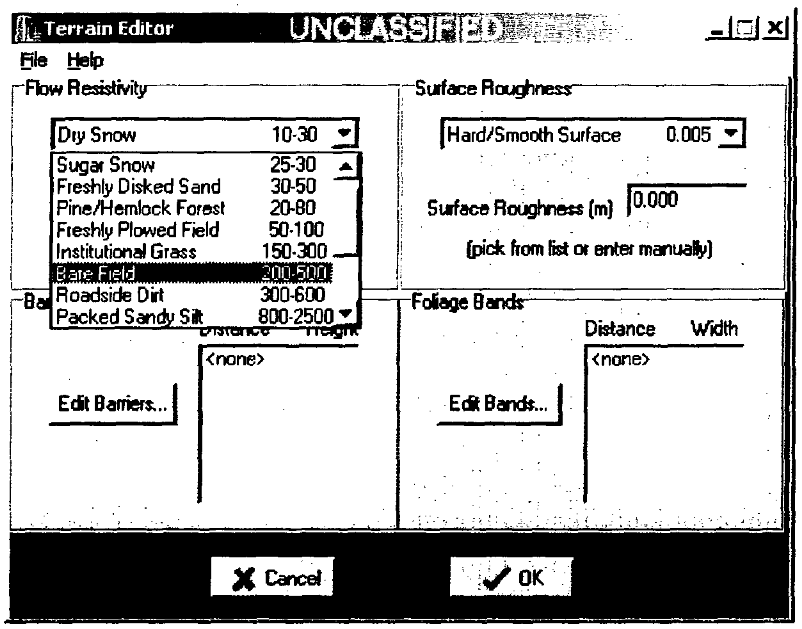

Figure 5 – Terrain Editor

Once the run is set up, the user clicks the Start button and for the Detection Range case, a popup window displays the basic result, as in Figure 6.

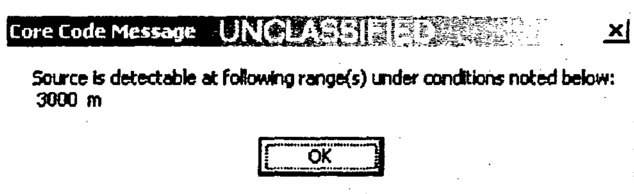

Figure 6 – Detection Range Result

After closing this window, the user can then view the source spectrum at the detection range, Figure 7, the signal-to-noise spectrum at the detector, Figure 8, and an attenuation spectrum displaying the total spectral attenuation and the portions contributed by each attenuation factor, Figure 9. The Source Levels (level that may not be exceeded at a specified range) and Propagate Levels (source spectrum at a specified range) calculations proceed in a similar fashion to the Detection Range Calculation just demonstrated.

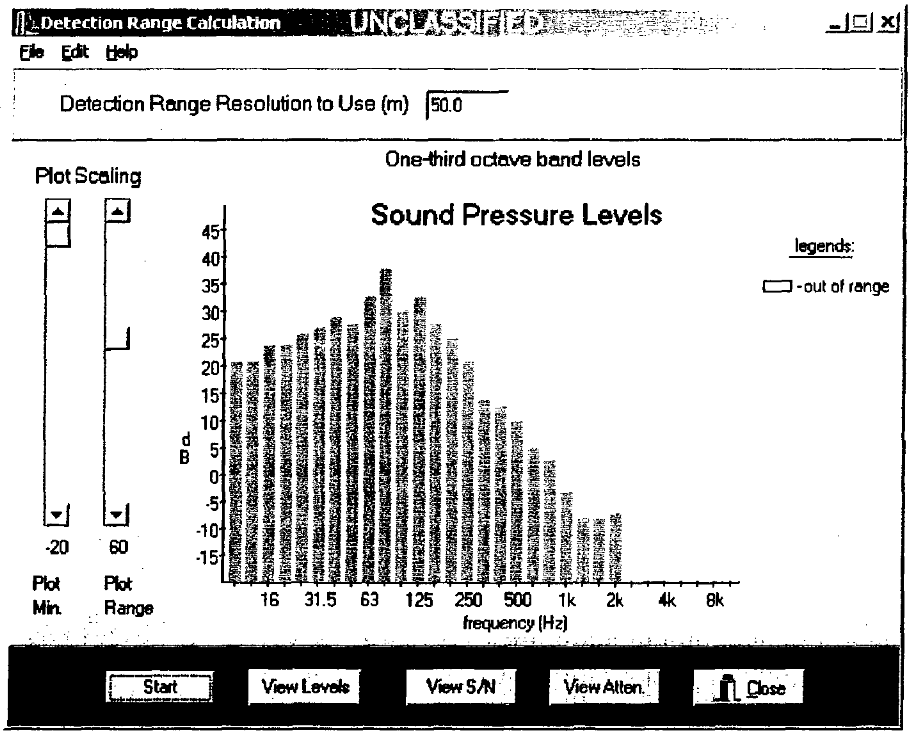

Figure 7 – Detection Range Screen with Source Spectrum at the Detector

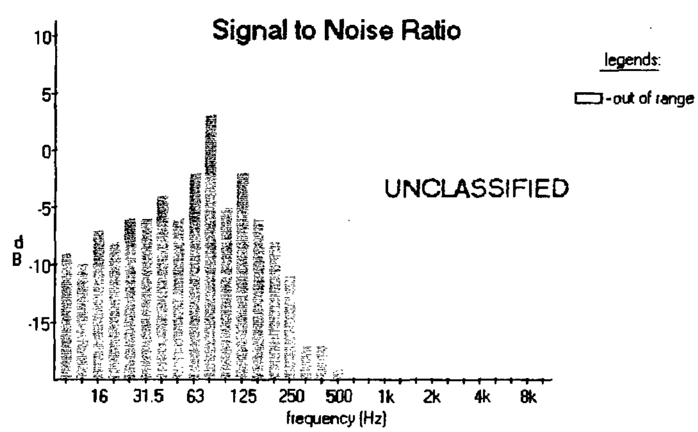

Figure 8 – Signal to Noise Ratio at the Detector

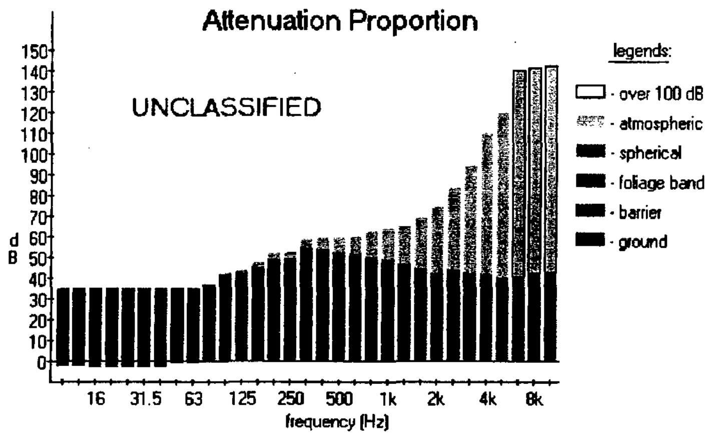

Figure 9 – Sum and Components of Attenuation

Selecting Sensitivity Analysis provides the input screen of Figure 10, where the user selects an input parameter to vary and a range of variation. When the Start button is clicked, ADRPM iterates over the range of values then displays a result such as Figure 11. Depending upon the number of steps, this calculation may be very time consuming.

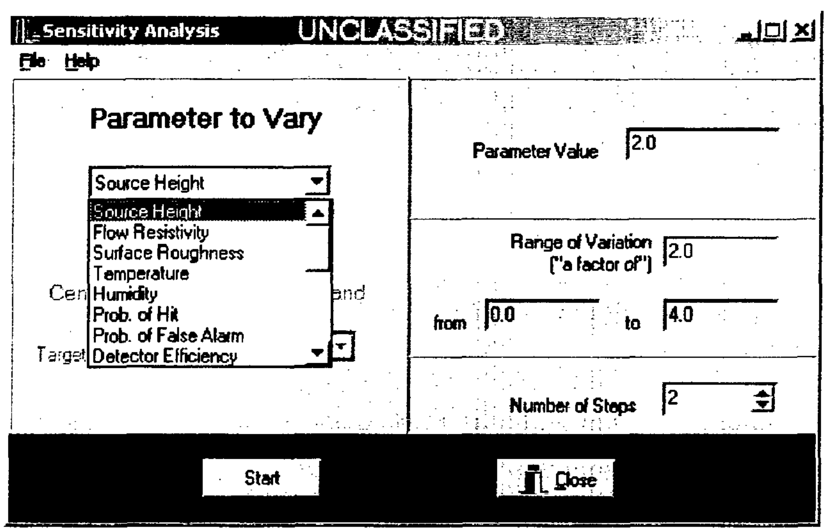

Figure 10 – Sensitivity Analysis Editor

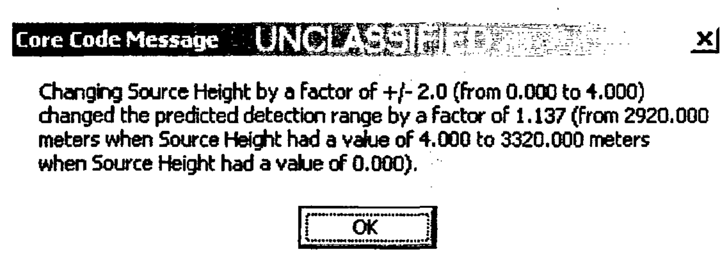

Figure 11 – Sensitivity Analysis Results

Future Developments

All of our testing so far, varying each of the input variables in turn, has shown exact agreement with the results from the HP version. Once the batch mode of ADRPM operation is implemented, we will process large amounts of actual field test data with both versions and compare results.

Unfortunately, the core code of ADRPM shows the impact of its evolution through various languages and authors. The code was translated years ago from FORTRAN to C but the result should charitably be called "C-TRAN", with artifacts such as global variables, cryptic variable names, duplicated code, and minimal comments. If our Windows version of ADRPM proves popular and useful, we may rewrite the core code to be more modular in object-oriented C++, or perhaps the more-readable Eiffel language. Then it would be much easier to try out different propagation models or other enhancements without the fear of "breaking" the model.

Conclusions

This paper represents the reintroduction of a proven, reasonably simple, non-commercial acoustic detection model to the ground vehicle survivability community. The model was ported to the PC platform making it available to the widest possible audience. We hope that it will be used during the design of new vehicles, and in the improvement of those already fielded. We also hope that users of this new ADRPM provide feedback on improvements to the model and suggestions as to the direction of its future evolution.

References

1: Fidell, S., Secrist, L., Harris, M., and Sneddon, M., "Development of Version 7 of an Acoustic Detection Range Prediction Model (ADRPM-7)", Technical Report 13397, Vols. I-III, U.S. Army Tank-Automotive Command, Warren, MI (1989)

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OPSEC REVIEW CERTIFICATION

(AR 530-1, Operations Security)

I am aware that there is foreign intelligence interest in open source publications. I have sufficient technical expertise in the subject matter of this paper to make a determination that the net benefit of this public release outweighs any potential damage.

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Name | Grade | Title

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Reviewer's Determination (check one) This report describes an acoustic propagation model and contains no military sensitive information. This model is very old technology and I see no reason to control the release of the report. Unclassified unlimited release is recommended. WM

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